Cortisol response in healthy and diseased dogs after stimulation with a depot formulation of synthetic ACTH

Sieber-Ruckstuhl, Nadja S ; Burkhardt, W A ; Hofer-Inteeworn, Nathalie ; Riond, Barbara ; Rast, I T ; Hofmann-Lehmann, R ; Reusch, Claudia E ; Boretti, Felicitas S

Abstract: BACKGROUND The ACTH stimulation test is used to evaluate the adrenocortical reserve. Recently, the availability of the synthetic ACTH formulation was limited, causing major problems in clinical practice. OBJECTIVES The objective of this study was to evaluate poststimulation peak cortisol concentrations and the duration of the stimulatory effect of a depot ACTH preparation in dogs. ANIMALS Twenty-two healthy dogs, 10 dogs with suspected hypoadrenocorticism (HA) and 15 dogs with suspected hyperadrenocorticism (HC). METHODS Prospective study. An ACTH stimulation test using a synthetic depot tetracosactide, administered intramuscularly (5 g/kg or at least 0.1 mL) was performed. Blood samples for determination of cortisol were taken immediately before and 1, 2, 3, 4, 6, and 24 hours after stimulation. RESULTS Peak cortisol concentrations were reached after 2-4 hours in all dogs. Cortisol concentrations 1 hour after stimulation were >9 g/dL in all healthy dogs and >5 g/dL in all dogs in which HA was excluded. None of the dogs with HA showed a cortisol-increase above the detection-limit of the assay. After 6 hours, cortisol concentrations had decreased in the healthy and HC group and were back to baseline after 24 hours. CONCLUSIONS AND CLINICAL IMPORTANCE The depot formulation can be used in place of the short-acting ACTH to evaluate the adrenocortical reserve. Blood for peak cortisol concentrations should be drawn 3 hours after stimulation in cases in which HC is suspected; in HA-suspected cases, blood sampling can take place after 1 hour. As the stimulatory effect is gone after 24 hours, interference with other hormonal tests is unlikely after that time.

DOI: https://doi.org/10.1111/jvim.13641

DOI: https://doi.org/10.1111/jvim.13641

Journal of Veterinary Internal Medicine
Open Access
ACVIM
American College of Veterinary Internal Medicine

J Vet Intern Med 2015;29:1541–1546

Cortisol Response in Healthy and Diseased Dogs after Stimulation with a Depot Formulation of Synthetic ACTH

N.S. Sieber-Ruckstuhl, W.A. Burkhardt, N. Hofer-Inteeworn, B. Riond, I.T. Rast, R. Hofmann-Lehmann, C.E. Reusch, and F.S. Boretti

Background: The ACTH stimulation test is used to evaluate the adrenocortical reserve. Recently, the availability of the synthetic ACTH formulation was limited, causing major problems in clinical practice.

Objectives: The objective of this study was to evaluate poststimulation peak cortisol concentrations and the duration of the stimulatory effect of a depot ACTH preparation in dogs.

Animals: Twenty-two healthy dogs, 10 dogs with suspected hypoadrenocorticism (HA) and 15 dogs with suspected hyperadrenocorticism (HC).

Methods: Prospective study. An ACTH stimulation test using a synthetic depot tetracosactide, administered intramuscularly (5 μg/kg or at least 0.1 mL) was performed. Blood samples for determination of cortisol were taken immediately before and 1, 2, 3, 4, 6, and 24 hours after stimulation.

Results: Peak cortisol concentrations were reached after 2–4 hours in all dogs. Cortisol concentrations 1 hour after stimulation were >9 μg/dL in all healthy dogs and >5 μg/dL in all dogs in which HA was excluded. None of the dogs with HA showed a cortisol-increase above the detection-limit of the assay. After 6 hours, cortisol concentrations had decreased in the healthy and HC group and were back to baseline after 24 hours.

Conclusions and Clinical Importance: The depot formulation can be used in place of the short-acting ACTH to evaluate the adrenocortical reserve. Blood for peak cortisol concentrations should be drawn 3 hours after stimulation in cases in which HC is suspected; in HA-suspected cases, blood sampling can take place after 1 hour. As the stimulatory effect is gone after 24 hours, interference with other hormonal tests is unlikely after that time.

Key words: Adrenocortical reserve; Canine; Synacthen depot.

The ACTH stimulation test has traditionally been recognized as an accurate measure to assess the functional reserve capacity of the adrenal cortex and serves as gold standard in diagnosing hypoadrenocorticism (HA) in dogs.[1,2] The test is also used to distinguish iatrogenic from spontaneous hyperadrenocorticism (HC) and to monitor trilostane or mitotane treatment.[3,4]

Several ACTH preparations are available. One of the most commonly used formulations is a synthetic polypeptide, which consists of the first 24 (of a total 39) amino acids of the ACTH, generally known as cosyntropin or tetracosactide. Tetracosactide is available in 2 formulations: a short-acting form for IV or IM use and a depot form for IM use only. The depot formulation contains inorganic zinc complexes, which adsorb the active substance, resulting in a protracted release. Recently, the availability of the short-acting tetracosactide was limited; in some countries it was not available at all. In contrast, the availability of the depot formulation has never been affected.

Abbreviations:

HA	hypoadrenocorticism
HC	hyperadrenocorticism
LDDS test	low-dose dexamethasone suppression test
PDH	pituitary-dependent hyperadrenocorticism

In human medicine, the depot tetracosactide is used for both therapeutic and diagnostic purposes. Among other things, it has been described in the treatment of rheumatoid arthritis, dermatosis (ie, pemphigus, psoriasis), or infantile myoclonic encephalopathy.[5,6] To diagnose adrenal insufficiency, the depot tetracosactide is used as a 5-hour test in which cortisol concentrations are determined before and every hour after stimulation for a 5-hour period.[7] According to the manufacturer, the duration of the stimulatory effect of the depot tetracosactide can be expected to last between 24 and 36 hours.

In veterinary medicine, the product has been evaluated in healthy dogs using 2 different concentrations (5 μg/kg and 250 μg/dog) and blood sampling has been performed during the first 3 hours after stimulation.[8] However, it is unknown whether peak serum cortisol concentrations in dogs are reached 3 hours after stimulation. In addition, the information as to what time after stimulation cortisol concentrations are back to baseline levels is lacking. Knowledge about the time of peak cortisol concentration is a prerequisite for correct

From the Clinic for Small Animal Internal Medicine, (Sieber-Ruckstuhl, Burkhardt, Hofer-Inteeworn, Rast, Reusch, Boretti); and the Clinical Laboratory, Vetsuisse Faculty University of Zurich, Zurich, Switzerland (Riond, Hofmann-Lehmann).

The work was done at the Clinic of Small Animal Internal Medicine, Vetsuisse Faculty University of Zurich, Zurich, Switzerland.

Corresponding author: C.E. Reusch, Clinic for Small Animal Internal Medicine, Vetsuisse Faculty University of Zurich, Winterthurerstrasse 260, CH-8057 Zurich, Switzerland; e-mail: creusch@vetclinics.uzh.ch.

Submitted May 13, 2015; Revised August 20, 2015; Accepted September 9, 2015.

DOI: 10.1111/jvim.13641

interpretation of the test and evaluation of adrenocortical reserve, and knowing the duration of the stimulatory effect is important to assess the risk of interference with other hormonal measurements. The use of the depot ACTH preparation has not yet been evaluated in dogs with adrenal diseases.

Therefore, the objective of this study was to evaluate the depot tetracosactide preparation in healthy dogs and in dogs with clinical signs consistent with HA or HC, with the aims of determining the time point of peak serum cortisol concentrations and the duration of increased cortisol concentrations after tetracosactide depot administration.

Materials and Methods

Animals

Twelve purpose-bred beagle-pinscher mixed-breed dogs (6 females and 6 males) with a median age of 2 years (range 1–2 years) and a median body weight of 14.8 kg (range 13–17 kg) were included. Dogs were housed in groups in standard kennels at the research unit of the Vetsuisse Faculty of the University of Zurich, fed a standard commercial maintenance pellet diet once daily, and had ad libitum access to water.

In addition, 10 healthy privately owned dogs from hospital personnel and students, including 2 intact males and 8 females (5 spayed), with a median age of 5 years (range 1.5–12 years) and a median body weight of 15.8 kg (range 6.9–27 kg) were used. They were determined to be healthy on the basis of their history and results of a physical examination plus hematologic and biochemical evaluation. None of the dogs had received any medication for at least 8 weeks before inclusion in the study except routine vaccination, deworming and heartworm prophylaxis.

Ten dogs with a clinical suspicion of HA were prospectively enrolled. All dogs had initially been suspected of having HA based on clinical signs or laboratory findings routinely seen in dogs with HA, such as vomiting, diarrhea, weakness, lethargy, hyperkalemia and hyponatremia. Blood and urine samples were collected for a complete blood count, serum biochemical profile and urinalysis. Work-up included an ACTH stimulation test using the depot preparation, which excluded HA when post-ACTH cortisol concentration was >5 μg/dL. Additional tests were abdominal ultrasonography (in particular adrenal glands) and measurement of endogenous ACTH. There were 5 males (1 castrated) and 5 females (4 spayed). Their median age was 6 years (range 0.5–14.0 years) and their median body weight 8.9 kg (range 4.9–48 kg).

Fifteen dogs with a clinical suspicion of HC were prospectively enrolled. Dogs previously treated with glucocorticoids, mineralocorticoids, progestagen, or trilostane were excluded from the study. They all underwent a complete hematologic and biochemical evaluation, urinalysis including urinary culture, low-dose dexamethasone suppression test (LDDS test: 0.01 mg/kg dexamethasone IV, blood sampling before, 4 and 8 hours thereafter), measurement of endogenous ACTH and an ultrasonographic examination of the adrenal glands. Hyperadrenocorticism was confirmed when the LDDS test yielded a positive result (serum cortisol concentration 8 hours after dexamethasone administration >1.0 μg/dL[9–11]) and treatment with trilostane showed an appropriate response (starting dose of 2 mg/kg; re-evaluations performed as described previously). Pituitary-dependent hyperadrenocorticism (PDH) was diagnosed on the basis of the dogs' concentration of endogenous ACTH and a symmetric ultrasonographic appearance, with or without enlargement, of their adrenal glands. There were 9 males (4 castrated) and 6 females (5 spayed). Their median age was 10 years (range 7–15 years) and their median body weight 13.4 kg (range 3.6–45.0 kg).

Informed consent of all pet owners was obtained before including the dogs in the study. Animal care was in accordance with the guidelines and directives established by the Animal Welfare Act of Switzerland. The study protocol was officially approved by the veterinary office of the canton of Zurich and was in accordance with the guidelines and directives established by the Animal Welfare Act of Switzerland (TVB 191/2013).

Analytical Procedures

All dogs underwent an ACTH stimulation test using a synthetic tetracosactide hexaacetate formulation with a concentration of 1,000 μg/mL.[a] For each test 5 μg/kg or at least 0.1 mL were administered intramuscularly (supra/infraspinatus of the left/right thoracic limb or quadriceps muscle of left/right hind limb) and blood samples (jugular venipuncture) were taken immediately before and 1, 2, 3, 4, 6, and 20–24 hours after stimulation. After clot retraction at room temperature, serum was harvested by low-speed centrifugation and transferred to tubes for storage at −20°C for later hormone assay. Cortisol concentrations were measured by chemiluminescence assay.[b] Sensitivity of the cortisol assay was 0.2 μg/dL. All samples of each dog were analyzed in the same run to minimize interassay variation. Endogenous ACTH before ACTH stimulation was determined by a chemiluminescence assay.[b] Blood was collected into chilled EDTA-coated tubes placed on ice and centrifuged at 4°C. Cortisol and endogenous ACTH measurements were performed in house twice a week; plasma was stored either at −20°C (cortisol) or at −80°C (ACTH) until assayed. Immediately before analysis, samples were thawed at room temperature.

Statistical Analyses

Data were analyzed with non-parametric statistical methods.[c,d] Differences between groups of dogs were tested by using the Kruskal–Wallis *H*-test and the Mann–Whitney *U*-test. Differences between the time points of the ACTH stimulation were tested by use of Friedman's repeated measures test and the Wilcoxon matched pairs test. All *P* values quoted are Bonferroni corrected. The level of significance was set at $P < .05$.

Results

No adverse reactions and no evidence of pain at the injection site after IM administration were noticed in any of the dogs during and after the stimulation test.

Healthy Dogs

Pre- and post-ACTH cortisol concentrations of all time points of the healthy dogs are summarized in Table 1. There was no significant difference between the values of healthy research dogs and healthy client-owned dogs at any time point; therefore, all healthy dogs were summarized in 1 group for further analysis.

Maximal median cortisol concentrations were reached after 3 hours. Peak cortisol concentrations occurred after 1 hour in 1, after 2 hours in 4, after 3 hours in 11 and after 4 hours in 6 dogs. Twenty-four hours after stimulation cortisol concentrations had again reached baseline concentrations. Cortisol concentrations 1, 2, 3,

Table 1. Baseline and stimulated cortisol concentrations (median, range) after administration of synthetic ACTH depot formulation.

	Pre-ACTH	Post-ACTH					
Diagnosis	0 hour	1 hour	2 hours	3 hours	4 hours	6 hours	24 hours
Healthy (n = 22)	1.4[a] (0.6–2.6)	9.3[b] (5.1–16.4)	11.3[c] (5.3–24.2)	12.2[c,d] (5.6–25.5)	9.7[b,c,d,e] (3.1–26.3)	2.7[f] (0.7–11.2)	1.3[a] (0.5–3.2)
Primary HA (n = 1)	<0.2	0.2	<0.2	<0.2	<0.2	nd	nd
Primary HA (n = 1)	<0.2	<0.2	<0.2	<0.2	<0.2	nd	nd
Iatrogenic HA (n = 1)	1.5	1.8	1.9	1.9	2.3	2.1	2.2
Non-HA (n = 7)	2[a] (1.5–3.7)	12.1[b] (9.8–18.6)	15.9[a,b,c] (13.2–26.5)	17.3[c] (13.1–27.2)	19.8[a,b,c] (2.9–30.9)	8.9[a,b,c] (0.7–26)	2.3[a,b,c] (0.4–6.4)
Suspicion of HC (n = 15)	2.9[a] (1.9–11.5)	17.0[b] (10.6–34.1)	20.5[c] (7.4–37.9)	24.4[b,c,d] (3.2–34.6)	18.3[b,c,e] (1.3–29.6)	9[b,f] (0.5–20.8)	3.5[a] (1.8–9.6)
HC (n = 10)	3.3[a] (1.9–11.5)	18.5[b] (13.8 –34.1)	25.5[c] (15.6–37.9)	24.8[c,d] (12.4–34.6)	24.2[b,c,e] (9.6–29.6)	16.5[b,f] (4–20.8)	4[a,b,c,d,e] (3.3–9.6)
Non-HC (n = 5)	2.6 (1.9–9.9)	14.3 (10.6–21.3)	15.1 (7.4–24.6)	16.4 (3.2–24.9)	14 (1.3–14.7)	8 (0.5–9)	2.7 (1.8–3.2)

HC: hyperadrenocorticism; non-HC: dogs with suspicion of HC, but negative low-dose dexamethasone suppression test result; HA: hypoadrenocorticism; non-HA: dogs with suspicion of HA, in which HA was excluded.

Within a group (row) different superscript letters indicate statistically significant differences between the time points ($P < .05$).

4, and 6 hours after stimulation were significantly higher than baseline cortisol concentrations (P: <.001, <.001, <.001, <.001, and .002) and concentrations after 24 hours (P: <.001, <.001, <.001, <.001, and .002; Fig 1).

Dogs with Clinical Suspicion of HA

Two dogs were diagnosed with primary HA (all post-ACTH cortisol concentrations < 0.2 μg/dL, cACTH > 1,250 pg/mL) and 1 dog with iatrogenic HA (all post-ACTH cortisol concentrations < 2.5 μg/dL, methylprednisolone application by private veterinarian 4 weeks previously). In 7 dogs, HA was excluded (post-ACTH > 5 μg/dL; non-HA group). Pre- and post-ACTH cortisol concentrations of the dogs with primary HA, with iatrogenic HA and with non-HA are summarized in Table 1.

In the non-HA group, maximal median cortisol concentrations were reached after 4 hours. Peak cortisol concentrations occurred after 2 hours in 1, after 3 hours in 1, and after 4 hours in 5 dogs. Cortisol concentrations 1 and 3 hours after stimulation were significantly higher than baseline cortisol concentration ($P = .036$ and .036; Fig 2).

Dogs With Clinical Suspicion of HC

Pre- and post-ACTH cortisol concentrations of the dogs with suspicion of HC are summarized in Table 1.

Maximal median cortisol concentrations were reached after 3 hours. Peak cortisol concentration occurred after 1 hour in 1, after 2 hours in 5, after 3 hours in 6, and after 4 hours in 2 dogs (1 dog missing). By 24 hours after stimulation cortisol concentrations had again reached baseline concentration. Cortisol concentrations 1, 2, 3, 4, and 6 hours after stimulation were significantly higher than baseline cortisol concentrations

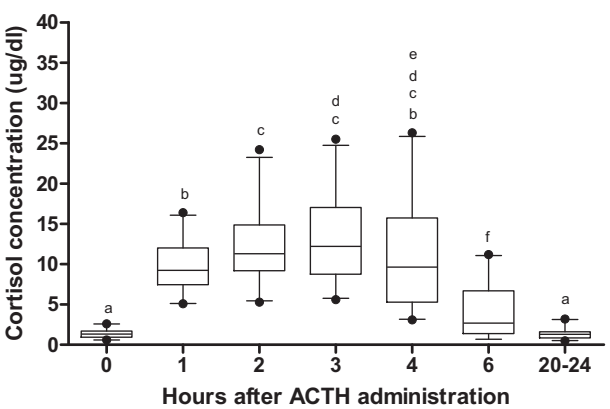

Fig 1. Serum cortisol concentrations before and after ACTH stimulation with a synthetic ACTH depot formulation in healthy dogs (n = 22). Each box represents the interquartile (ie, 25th to 75th percentile) range, the horizontal line within the box represents the median value, the bars represent the 5th to 95th percentile, and the circles represent outlying data points. Different letters indicate statistically significant differences between the time points ($P < .05$).

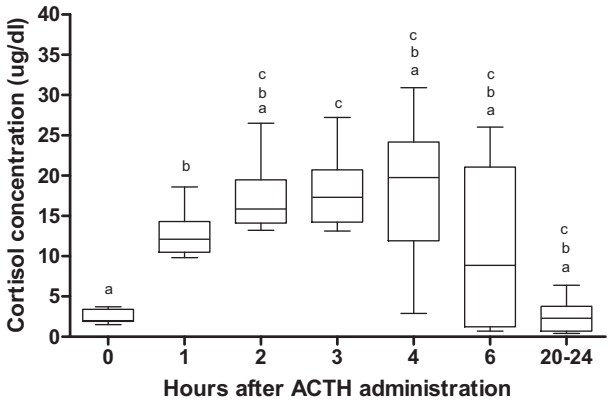

Fig 2. Serum cortisol concentrations before and after ACTH stimulation with a synthetic ACTH depot formulation in dogs with initial suspicion of hypoadrenocorticism (HA), but in which HA was excluded (n = 7). Each box represents the interquartile (ie, 25th to 75th percentile) range; the horizontal line within the box represents the median value; the bars represent the 5th to 95th percentile; the circles represent outlying data points. Different letters indicate statistically significant differences between the time points ($P < .05$).

($P = .002$, .002, .002, .006, and .026) and concentrations after 24 hours ($P = .01$, .01, .016, .02, and .034) (Fig 3A).

In 10 dogs, HC was confirmed (all PDH; HC group) and in 5 dogs HC was excluded (negative LDDS test result; non-HC group). Two of these dogs were diagnosed with a hormonally inactive adrenal mass, 1 suffered from diabetes mellitus and 2 dogs had PU/PD of unclear origin. Cortisol concentrations at 24 hours after stimulation were significantly different between the HC and the non-HC group ($P = .02$; Fig 3B).

Comparison between Groups (Healthy, HC, Non-HC, Non-HA)

The most distinctive differences were seen between the healthy dogs and the HC dogs (all PDH). Baseline cortisol and cortisol concentrations 1, 2, 3, 4, 6, and 24 hours after stimulation were significantly higher in dogs with HC compared with those in healthy dogs (P: <.001, <.001, <.001, <.001, .002, .002 and <.001; Fig 4).

In the non-HC group, baseline and cortisol concentrations 1 and 24 hours after stimulation (P: <.001, .02, and .01) and in the non-HA group, baseline cortisol and cortisol concentrations 1 hour after stimulation were significantly different from those of the healthy dogs (P: .004 and .048; Fig 4).

Comparing the HC and the non-HA groups, cortisol concentrations at 1 and 2 hours after stimulation were significantly different ($P = .01$ and .032; Fig 4). Between the non-HC and the non-HA groups, no differences were detected.

Discussion

One of the goals of this study was to evaluate peak cortisol concentrations after stimulation with depot tetracosactide in healthy dogs and dogs with suspicion of adrenal diseases. Peak median serum cortisol concentrations were reached after 3 hours in healthy dogs and dogs with suspected HC and after 4 hours in dogs suspected of having HA.

However, time point of peak cortisol concentration varied individually lying between 1–4, 1–4, and 2–4 hours in the healthy, non-HA group and in dogs suspected of having HC, respectively. It is therefore impossible to recommend an optimal sampling time point after stimulation with which the peak cortisol concentrations of all adrenal diseases can be detected. However, considering the objective in performing an ACTH stimulation test, it is different for hypo- and hyperfunctioning adrenal glands. In dogs suspected of suffering from HA, the goal is either to exclude HA with a

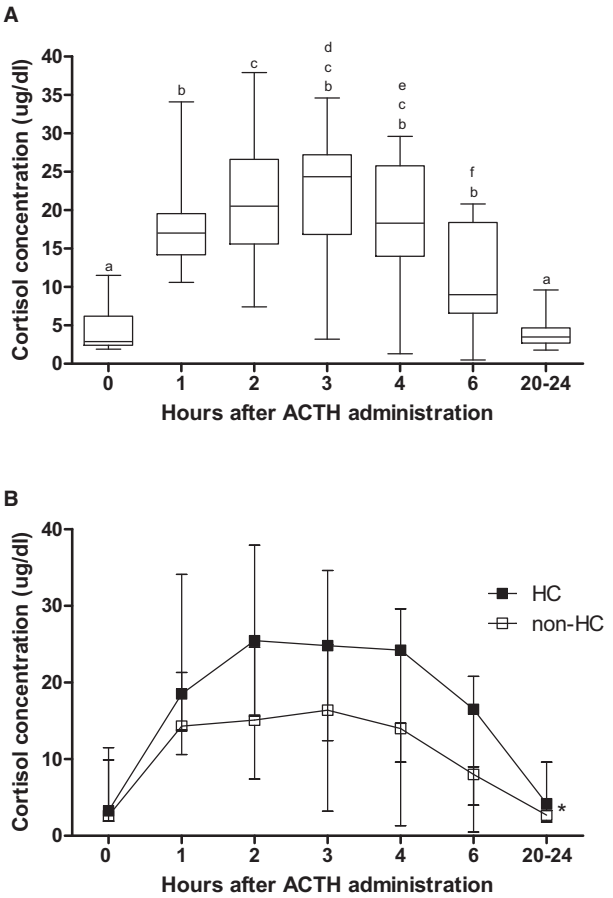

Fig 3. **(A)** Serum cortisol concentrations before and after ACTH stimulation with a synthetic ACTH depot formulation in dogs with clinical suspicion of hyperadrenocorticism (HC; n = 15). Each box represents the interquartile (ie, 25th to 75th percentile) range; the horizontal line within the box represents the median value; the bars represent the 5th to 95th percentile; the circles represent outlying data points. Different letters indicate statistically significant differences between the time points ($P < .05$). **(B)** Median and range of serum cortisol concentrations before and after ACTH stimulation with a synthetic ACTH depot formulation in dogs with confirmed HC (n = 10) and dogs with suspicion of HC but normal low-dose dexamethasone suppression (LDDS) test (non-HC, n = 5). *Significant difference between the 2 groups.

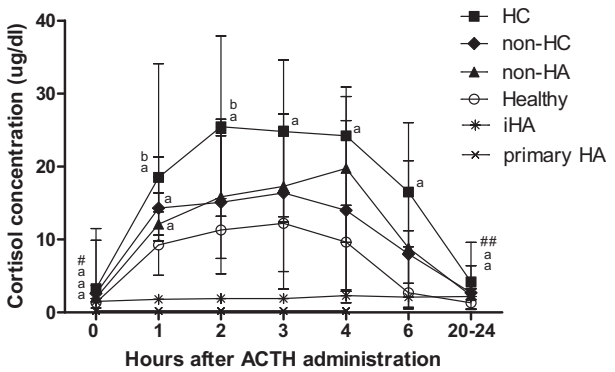

Fig 4. Serum cortisol concentrations before and after ACTH stimulation in healthy dogs (healthy, n = 22), dogs with hyperadrenocorticism (HC, n = 10), dogs with initial suspicion of HC, but negative low-dose dexamethasone suppression (LDDS) test results (non-HC, n = 5), dogs with initial suspicion of hypoadrenocorticism (HA), but normal ACTH stimulation (non-HA, n = 7), dog with iatrogenic HA (iHA, n = 1) and dogs with primary HA (primary HA, n = 2). For healthy, HC, non-HC and non-HA, median and range are reported. For iHA and HA, single values of each individual are reported. Statistical comparison was performed between healthy, HC, non-HC and non-HA, only. [a]Significant difference to healthy dogs, [b]significant difference to non-HA dogs. [#aaa]Applies to HC, non-HC and non-HA. [##aa]Belongs to HC and non-HC.

sufficient stimulation (post-ACTH cortisol > 5 μg/dL) or to confirm HA by an insufficient stimulation (post-ACTH cortisol < 2 μg/dL). This goal would have been reached in our study, if blood had been taken already 1 hour after stimulation. All dogs suspected of having HA but in which it was excluded had a 1-hour cortisol concentration of >9 μg/dL; in those with confirmed HA it was <0.2 μg/dL. In addition, all healthy dogs had a 1-hour cortisol concentration >5 μg/dL. Therefore, it could be concluded that for the diagnosis of HA in dogs, using the depot tetracosactide, a blood sample before and 1 hour after stimulation with 5 μg/kg is sufficient. This information is of great importance, because if there is high suspicion of HA and the dog is in critical clinical condition, administration of corticosteroids should not be delayed. Exogenous synthetic corticosteroids, however, can cross-react with cortisol assays or bear the risk of adrenal gland suppression due to the negative feedback mechanism, which as a consequence would lead to blunted stimulation and misinterpretation of the test.

The objective of an ACTH stimulation test in dogs suspected of having HC and in which trilostane treatment has to be monitored is different. In these situations, knowledge of the peak cortisol concentration after stimulation is the important information. From our data, blood for the diagnosis of HC should be drawn between 2 and 4 hours after stimulation, as within this time period the likelihood of getting the peak cortisol concentration is highest. Blood sampling after 1 hour in these cases might lead to a falsely low test result. Based on our data, no conclusion can be drawn as to which time point should be chosen for monitoring the trilostane treatment, as these dogs were not evaluated. It is merely speculative that in these cases, the 1-hour value might also be too early to assess the maximal suppression of the cortisol synthesis during trilostane treatment. Further studies are needed to address this issue.

Another aspect of peak cortisol concentration is the magnitude of the peak. Two of the healthy dogs had post-ACTH cortisol values above the originally established normal reference interval, with values of 23.2 and 26.3 μg/dL. Also, in individual dogs with suspected HA, cortisol concentrations of up to 30 μg/dL could be observed. Although these high values could be interpreted as being consistent with HC, none of the healthy and certainly none of the HA-suspected dogs had clinical signs suggestive of HC. In agreement with our data, the study of Ginel et al[8] evaluating depot tetracosactide in healthy Greyhounds revealed peak cortisol concentrations with values up to 30 μg/dL. One might assume that the depot product itself could lead to higher cortisol concentrations compared to the short-acting ACTH. However, a study evaluating short-acting ACTH for the diagnosis of HA in dogs reported similar results.[12] Values for their dogs, using a dose of 5 μg/kg, reached cortisol concentrations of up to 27.3 μg/dL; 1 dog even had a value of 41.6 μg/dL without any evidence of HC and with a final diagnosis of inflammatory bowel disease. Therefore, we think it is more likely that the increased response could have been caused by stress (white-coat effect) of the hospitalization and the blood sampling, or it could be a sign of the concurrent illness of the dogs.

A further interesting and important finding was that peak cortisol concentrations reached values of >22 μg/dL in 2 of the 5 dogs where HC was suspected but not confirmed, which according to published reference values should be considered abnormal.[3,13,14] However, these reference values were established using older and different assays. Care must be taken in adapting these reference values, as it is possible that the magnitude of peak concentration can reflect differences in the assays used to measure cortisol. In human medicine, it was shown that cortisol results from the same ACTH test are quite different when measured by 4 commonly used assays.[15] For the same cut-off value, it was possible to have a negative test result with one and a positive result with another assay. The authors concluded that establishing "normal peak" responses rely on the assay that is used. This is likely to be the case in veterinary medicine as well. Therefore, criteria for test interpretation probably need to be reestablished and the cut-off level for an abnormal test result should be newly defined with the currently used assays. This has already been suggested in the consensus statement of the ACVIM about the diagnosis of spontaneous canine HC.[4]

A second goal of this study was to assess the duration of increased cortisol concentrations after depot tetracosactide administration. We were able to show that after 24 hours the plasma cortisol concentrations were back to baseline levels in both the healthy dogs

and patient groups. This is of importance, as especially in dogs with suspected HC, a long duration of increased cortisol concentrations after ACTH administration carries the risk of interference with a LDDS test that may be performed the next day. In human medicine, plasma ACTH concentrations have been determined in healthy volunteers after the administration of depot ACTH.[16] While with the use of the short-acting ACTH preparation, ACTH concentrations dropped to undetectable levels 2 hours after injection, the use of the depot preparation led to increased plasma concentrations up to 8 hours after administration.[16] However, levels were undetectable after 24 hours in all subjects.[16] This finding is somewhat reflected in our data: although we did not determine plasma ACTH concentrations, we observed a substantially decreased cortisol concentration after 6 hours as compared to 3 hours and, as mentioned above, values were back to baseline concentrations after 24 hours. Interestingly, dogs with confirmed HC still had higher cortisol concentrations after 24 hours compared to dogs in which HC was excluded. This shows that in dogs with hyperfunctioning adrenal glands, exogenous ACTH can result in protracted cortisol secretion in comparison with dogs with normal adrenal function. Alternatively, it can reflect a decreased cortisol clearance in dogs with HC.

In conclusion, our data show that the depot tetracosactide may be used in place of the short-acting product for evaluation of the hypothalamic–pituitary–adrenal axis in dogs with adrenal malfunction. Blood sampling can take place 1 hour after stimulation in dogs with suspected HA. However, special attention has to be paid in the diagnostic evaluation of HC, as blood sampling 1 hour after stimulation does not reveal maximal stimulation. Nonetheless, the LDDS test can be performed 24 hours after depot tetracosactide administration without risk of interference.

Footnotes

[a] Synacthen Depot®, Novartis Pharma Schweiz AG, Bern, Switzerland
[b] DPC Immulite® 1,000, Siemens Schweiz AG, Zurich, Switzerland
[c] GraphPad Prism6, Graph Pad Software, San Diego, CA, USA
[d] SPSS 22.0 for Windows, SPSS Inc, Chicago, IL, USA

Acknowledgments

The authors gratefully acknowledge the veterinarians of the Clinic for Small Animal Internal Medicine for their contribution of cases. We thank all the dog owners for their assistance and willingness to take part in this study. This study was supported by Hill's Provet AG Switzerland, who kindly donated dog food for the group of healthy dogs.

Conflict of Interest Declaration: Authors disclose no conflict of interest.

Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

References

1. Greco DS. Hypoadrenocorticism in small animals. Clin Tech Small Anim Pract 2007;22:32–35.
2. Knitzer PP, Peterson ME. Primary and secondary canine hypoadrenocorticism. Vet Clin North Am Small Anim Pract 1097;27:349–357.
3. Herrtage ME, Ramsey IK. Canine hyperadrenocorticism. In: Mooney CT, Peterson ME, eds. BSAVA Manual of Canine and Feline Endocrinology, 4th ed. Quedgeley, Gloucester: British Small Animal Veterinary Association; 2012:167–189.
4. Behrend EN, Kooistra HS, Nelson R, et al. Diagnosis of spontaneous canine hyperadrenocorticism: 2012 ACVIM consensus statement (small animal). J Vet Intern Med 2013;27:1292–1304.
5. Rucklidge MW, Yentis SM, Paech MJ. Synacthen Depot for the treatment of postdural puncture headache. Anaesthesia 2004;59:138–141.
6. Taylor WJ, Rajapakse CN, Harris KA, et al. Inpatient treatment of rheumatoid arthritis with synacthen depot: A double blind placebo controlled trial with 6 month followup. J Rheumatol 1999;26:2544–2550.
7. Synacthen® Depot (Tetracosactidum) [package insert]. Rotkreuz, Schweiz: Novartis; 2012.
8. Ginel PJ, Sileo MT, Blanco B, et al. Evaluation of serum concentrations of cortisol and sex hormones of adrenal gland origin after stimulation with two synthetic ACTH preparations in clinically normal dogs. Am J Vet Res 2012;73:237–241.
9. Burkhardt WA, Boretti FS, Reusch CE, Sieber-Ruckstuhl NS. Evaluation of baseline cortisol, endogenous ACTH, and cortisol/ACTH ratio to monitor trilostane treatment in dogs with pituitary-dependent hypercortisolism. J Vet Intern Med 2013;27:919–923.
10. Quante S, Boretti FS, Kook PH, et al. Urinary catecholamine and metanephrine to creatinine ratios in dogs with hyperadrenocorticism or pheochromocytoma, and in healthy dogs. J Vet Intern Med 2010;24:1093–1097.
11. Sieber-Ruckstuhl NS, Boretti FS, Wenger M, et al. Serum concentrations of cortisol and cortisone in healthy dogs and dogs with pituitary-dependent hyperadrenocorticism treated with trilostane. Vet Rec 2008;163:477–481.
12. Lathan P, Scott-Moncrieff JC, Wills RW. Use of the cortisol-to-ACTH ratio for diagnosis of primary hypoadrenocorticism in dogs. J Vet Intern Med 2014;28:1546–1550.
13. Feldman EC. Comparison of ACTH response and dexamethasone suppression as screening tests in canine hyperadrenocorticism. J Am Vet Med Assoc 1983;182:506–510.
14. Peterson ME. Diagnosis of hyperadrenocorticism in dogs. Clin Tech Small Anim Pract 2007;22:2–11.
15. Clark PM, Neylon I, Raggatt PR, et al. Defining the normal cortisol response to the short Synacthen test: Implications for the investigation of hypothalamic–pituitary disorders. Clin Endocrinol (Oxf) 1998;49:287–292.
16. Chaabo A, de Ceaurriz J, Buisson C, et al. Simultaneous quantification and qualification of synacthen in plasma. Anal Bioanal Chem 2011;399:1835–1843.